Research Scholar Details	
Name Number	Mr. Sumit Suhas Aole
Mobile	+91-9769019857
Email id	sumit.aole@gmail.com
Category	Open
Subject	Instrumentation Engineering
Faculty	Science and Technology
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Research Topic	Development of Controllers for Rehabilitation Robotic Device
Research Center	Shri Guru Gobind Singhji Institute of Engineering and Technology, Vishnupuri, Nanded
Permanent address	C/o Prakash Aole, Balaji Ward, Near Ankur Hospital, Chandrapur. 442401
Residential address	C/o Mr. Kokare, Amrut Residency Flat no. 307, Third Floor, Near SGGSIE&T, Vishnupuri, Nanded
Research Guide/Supervisor Details	
Name	Dr. L. M. Waghmare
Mobile Number	+91-9822663185
Email id	lmwaghmare@yahoo.com
Designation	Professor, Instrumentation Engg. Department
Institute	Shri Guru Gobind Singhji Institute of Engineering and Technology, Vishnupuri, Nanded

“Development of Controllers for Rehabilitation Robotic Device”

Ph.D. Workplan

Submitted to

Swami Ramanand Teerth Marathwada University, Nanded

Submitted by:

Mr. Sumit S. Aole,

Research Scholar,

Department of Instrumentation Engineering,

Shri Guru Gobind Singhji Institute of Engineering and Technology, Vishnupuri, Nanded.

Guided by:

Dr. L. M. Waghmare,

Professor,

Department of Instrumentation Engineering,

Shri Guru Gobind Singhji Institute of Engineering and Technology, Vishnupuri, Nanded.

1. A brief resume of proposed work /problem.

The progress has been made in the fields of welfare robotics, bio-mechatronics and/or control systems to develop motion assistance and/or rehabilitative robotic devices/exoskeletons which to serve individuals in a better way of their daily life. However, we are still far from the desired goal, as existing devices have not yet been able to restore body mobility or function. Apart from the limitations in designing the proper hardware, the development of smart control algorithms is another major issue that needs to be properly addressed.

The typical position control methods include computed torque control, sliding mode control, adaptive control and intelligent control. Computed torque control is a kind of control method of real time kinetic compensation based on the system model, but it is difficult to guarantee the convergence of the algorithm when modeling errors occur in the robot system [1]. SMC belongs to "sliding surface motion" in the system dynamic process based on current state, it has the advantages of parameter variation and disturbance insensitivity, but, it is prone to chatter [2]. Adaptive control is to get continuous extraction of controlled object information in the running process of the system, so as to make the control model perfect, however, the parameter identification is required, the control is complex and the computation is large [3]. And, intelligent control such as neural network, is aimed at complex, nonlinear and uncertain robotic systems, which has the ability to approximate any nonlinear function, but the training is difficult, and the calculation speed is slow [4].

The proposed research is based on the Investigation of difficult problems which occurs in operation of Rehabilitation Robotics device, controllers such as tracking control with guaranteed high accuracy and speed. The approach is to developed the framework based application of various control strategies.

2. Introduction to proposed research topic.

The rehabilitation robotics is an area of robotics which deals with the action of restoring someone to health or normal life through training and therapy or by providing an auxiliary solution for their functional disabilities with the help of robots. Their function is covering widely and includes diet, work, entertainment, walking and supplementary personal hygiene et al. The research area requires a knowledge of the fields like rehabilitation medicine, Mechanics, Biomechanics, electronics, Material science, etc. The rehabilitation robotics is one of the emerging technology in world with the increasing demand. With the development in research and application of advanced robot technology in the field of rehabilitation, the performance requirements of rehabilitation robots are very strict. The goal of rehabilitation robotics research is to help disabled patients recover or compensate for the loss of limb movement and make them have an ability to complete the most basic living.

The combination of industrial robot and medical robot is rehabilitation robot, and the robot system for the disabled service was put into production in the 20th century 60's to70's firstly. Practice has proved that these attempts have failed and there are two reasons for the failure, one of them is that the design is not ideal especially man-machine interface and another is not technical level but unit price too high. When 1980s is the initial stage of rehabilitation robot, the United States, Britain and Canada are leading the way in the field of rehabilitation robot. Before 1990, 56 research centers in the world are located in 5 industrial zones and they are North America, the UK, Canada, the European continent, and the Scandinavia Peninsula and Japan. After 1990, the research of rehabilitation robot becomes comprehensive development [5]. The existing rehabilitation robots can be classified from different angles. It can be roughly divided into auxiliary, replacement, training and therapeutic type et al according to the function [6-8]. It can also be divided into the upper and limb rehabilitation robots according to the body parts [9-11], external skeletal and embedded type according to man-machine combination mode [12-13], fixed and mobile type according to its movement way [14-15].

3. Survey or review of literature and development in the relevant subject.

In rehabilitation robotics, most of existing controllers designed for position control of exoskeleton robots are linear which may not be suitable for exoskeleton robots having complex structures under heavy uncertainties. sliding mode controller (SMC) is designed for position control of a 5 degrees of freedom exoskeleton robot dedicated for upper limb rehabilitation. The proposed sliding mode controller will be compared to a proportional-integral-derivative (PID) controller in order to verify its control performance. Mechanical design and control of an exoskeleton robot for shoulder rehabilitation after stroke in which SMC is used and mechanical design of a new 3 degrees of freedom (DOF) exoskeleton robot for shoulder joint rehabilitation is presented. The parameters of the SMC are tuned using Genetic Algorithm (GA) [16-17]. an upper-limb exoskeleton intended to assist the rehabilitation training of shoulder, elbow and wrist. therapeutic exoskeleton with anthropomorphic structure able to match the upper-limb anatomy and enable natural human-robot interaction. A modified sliding mode control (SMC) strategy consisting of a proportional-integral derivative (PID) sliding surface and a fuzzy hitting control law is developed to guarantee robust tracking performance and reduce the chattering effect.[18] The Lyapunov theorem is utilized to demonstrate the system stability.

For Gait rehabilitation is impedance based controller and robust sliding mode controller is compared in which robust SMC can accurately and robustly control the Human-inspired Robotic Exoskeleton (HuREx) device [19]. sliding mode controller has the potential to be used as a continues passive machine (CPM) resulting in improved recovery of injured hand for patients after stroke or post-surgical training. five different controllers, computed torque control (CTC), PD, PID, and two sliding mode controllers (SMC). It was shown that the second sliding mode controller resulted in improved trajectories that were chosen based on the natural hand movements [20]. A robust design of an adaptive Assist-As-Needed controller for a cable robot is given in which Robustifying terms are added to the controller to deal with structured and unstructured uncertainties in dynamics of the robot [21]. For lower limb rehabilitation robot, the sliding mode control (SMC) method, and the fuzzy compensation method is introduced to reduce disturbances this method has good trajectory tracking ability and stability in the presence of modeling errors and other disturbances when compared with the traditional computed torque control [22]. a trajectory tracking algorithm using a nonlinear sliding mode controller (SMC). To eliminate the chattering of conventional SMC, we employed the concept of boundary layer technique. the SMC can effectively use for upper limb rehabilitation [23].

4. Objectives of the research and proposed hypothesis.

a. To study and design various control algorithms used for rehabilitation robotics device.
b. To analyze the performance of the conventional controllers and proposed control algorithms through simulations on the predefined trajectories for rehabilitation robotics device.
c. To investigate the effect of the parameter variation for rehabilitation robotics device.
d. To obtain positioning accuracy and repeatability.
e. Experimental verification of simulation results.

5. Methodology to be used and adopted.

The overall goal of this research is to develop a new controller for robot-assisted rehabilitation system for people with a functional disability. Rehabilitation method is investigated, wherein the robot acts as an assistive device to provide the therapeutic training through simulating the kinematics and dynamics of the movements. Trajectories of healthy subjects and post-stroke patients were recorded by some motion tracking system in measurement laboratory. A various control strategy is to be studied, flaws and merits in them are identified through simulations on the predefined trajectories and feasible, possible modification is carried out to make it more robust compared to existing ones.

6. Importance of the study-

***International status & *National status**

The number of disabled people in Spain had gone up due to aging. This means the number of assistance has gone up. The rehabilitation robot is very popular in Spain because it is an acceptable cost, and there are many people in Spain that has strokes and need assistance afterward. Rehabilitation robotics are very popular with people who have suffered a stroke because the proprioceptive neuromuscular facilitation method is applied. When you suffer a stroke, your nervous system becomes damage in most cases causing people to have disability for six months after the stroke. The robot would be able to carry out exercises a therapist would carry out but the robot will do some exercises that are not so easy to be carried out by a human being [24] The pneumatic robot helps people who have had strokes or any other illness that has caused a disorder with their upper limb [25]

Robots involved in the rehabilitation of a patient has a few positive aspects. One of the positive aspects is the fact that you can repeat the process or exercise as many times as you wish. Another positive aspect is the fact that you can get exact measurements of their improvement or

decline. You can get the exact measurements through the sensors on the device. While the device is taking a measurement, you need to be careful because the device can be disrupted once it is done because of the different movements the patient does to get out [26] The rehabilitation robot can apply constant therapy for long periods. The rehabilitation robot is a wonderful device to use according to many therapists, scientists, and patients that have gone through the therapy. In the process of a recovery the rehabilitation robot is unable to understand the patient's needs like a well experienced therapist would [24] The robot is unable to understand now but in the future the device will be able to understand. Another plus of having a rehabilitation robot is that there is no physical effort put into work by the therapist.

Ekso Bionics is currently developing and manufacturing intelligently powered exoskeleton bionic devices that can be strapped on as wearable robots to enhance the strength, mobility, and endurance of soldiers and paraplegics. Tyromotion is currently developing and manufacturing a set of intelligent rehabilitation devices for the upper extremity. The hand rehabilitation robot called AMADEO offers a range of rehabilitation strategies including passive, assistive, ROM, force and haptic training. The arm rehabilitation robot called DIEGO offers bilateral arm therapy including assistive force for weight reduction and full 3D tracking of the arm movement for augemented feedback training in a virtual reality environment.

7. Proposed work plan with a tentative chapter scheme

Chapter 1	Introduction
Chapter 2	Literature Review
Chapter 3	Identification of control techniques for rehabilitation Robotics device.
Chapter 4	Modeling & Application of new proposed methodology Design of Controllers.
Chapter 5	Real-Time Experiments
Chapter 6	Conclusion
Chapter 7	Future Scope & Bibliography

8. Year wise plan of work and targets to be achieved

Work Description	year	Cumulative Completion Percentage (%)
Literature review	2017-2018 First Year	**10**
Identification of control technique to be used		**25**
Modeling & Application of new proposed methodology	2018-2019 Second Year	**45**
Real-Time Experimentation		**65**
Debugging & Report preparation	2019-2020 Third Year	**70**
Final project report and publication		**100**

9. Expected outcome.

1. This research will provide the positioning accuracy and repeatability which is helpful in various operations like medical robotics, industrial robotics.
2. An accurate path tracking result in the safe operation of the robots.
3. The control strategies will improve the overall performance by rejection the unknown disturbance.
4. This research will result in increase of efficiency and stabilization of the vibration of rehabilitation device.

10. Bibliography / References.

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Mr. Sumit S. Aole
Research Scholar

Dr. L. M. Waghmare
Research Guide/Supervisor